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DESIGN AND EXPERIMENTAL STUDY OF SEMI ACTIVE SYSTEM OF MR DAMPER FOR VIBRATION CONTROL

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ABSTRACT

Semi active control systems that offer the reliability of passive control systems, as well as the versatility and adaptability of active control systems have received significant attention for structural vibration control. Magneto-Rheological (MR) fluid dampers have emerged as such a class of semi active damping devices. By activating the MR fluid contained in the device through magnetic field, it can reversibly change from liquid to semisolid in milliseconds, which results in a continuously controllable device. The designs of nonlinear adaptive control systems for reducing vibration transmission in applications, such as transportation systems include suspension systems. Magneto-rheological dampers use a novel class of smart fluid, whose apparent viscosity changes, as it is exposed to a magnetic field. The developed adaptive control scheme is designed to deal with the nonlinearities and uncertainties that commonly arise in most suspension applications.

The present research is about numerical study evaluation of the controllers, on a seat suspension for heavy vehicles. The analytical evaluation indicates the effectiveness of the proposed adaptive control technique, in controlling vibration transmission, in the presence of both system nonlinearities and uncertainties. This work will provide a detailed account of the modeling, dynamic analysis, adaptive control development, and testing that will be performed throughout.

KEYWORDS: Magneto-Rheological (MR) Fluid, Damping Devices & Suspension Systems

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Original Article

INTRODUCTION

Magneto Rheological dampers are filled with magneto rheological fluid, which is controlled by magnetic field using electro magnet. The MR fluid can reversely change from free flowing linear viscous fluid to semi semisolid, with controllable yield strength in fraction of a second and used as automobile suspension for vibration [1]. The research designers developed the MR dampers as for ease of robustness, mechanical simplicity, low power consumption and fast response [2-4]. The modeling of MR dampers are for proper control of strategy to effective damper capacity [5-6]. The design of automobile suspension made a promise in effective design performance of MR dampers. MR effects create a dynamic performance capacity providing semi active control, where, damper force is controlled by electric current [7-9]. These can provide large force outputs for small change in current input

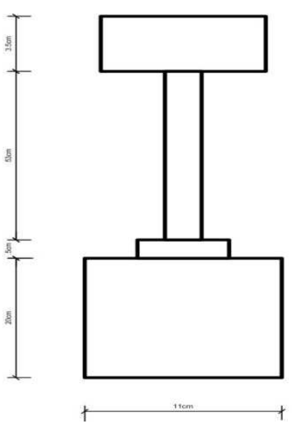
[10]. In the present research, the damping characteristics, with and without loadings were studied for reducing vibrations of a system [11]. Semi-active vibration control devices have received significant attention, because they can offer combined advantages of both passive and active control systems [12-14].

METHODS

Experimental Design

The design of the MR damper is based upon the application of load acting on the piston, which forces the piston downwards into the fluid and generation of magnetic field to the fluid. The amount of load applied depends upon the fluid density and intensity of magnetic field and magnetic particles size which added to the fluid. The load should be applied accordingly, in order to get the good damping of the damper. Initially, a permanent magnet is used to apply the magnetic field to the fluid and can vary the magnetic field as needed, by putting or removing permanent magnets located within the piston, and flat shaped nozzle is used to pass the fluid through the annulus hole. But, shocks are created at the bottom of the cylinder, which resists the flow of the fluid. Therefore, later on, a convergent nozzle is used to avoid the formation of shock waves within the damper, and permanent magnets are replaced by a copper coils to generate the magnetic field to the fluid, by supplying power to the coil, externally. It allows the coil to generate appropriate magnetic field, which intensity is more than that of the use of a permanent magnet.

Catia and AutoCAD drawings are prepared, according to the dimensions and all the parts of the damper are labeled in the AutoCAD drafting software. Following are the parts of the damper designed in Catia and AutoCAD.



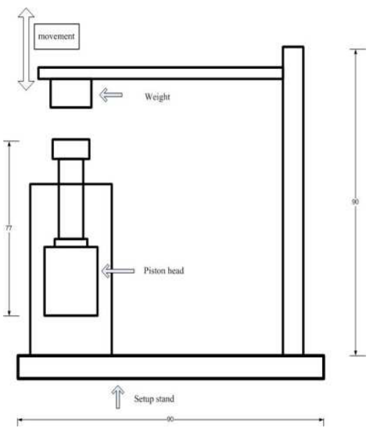


Figure 1: -D Piston Rod   Figure 2: D MR Damper Structure

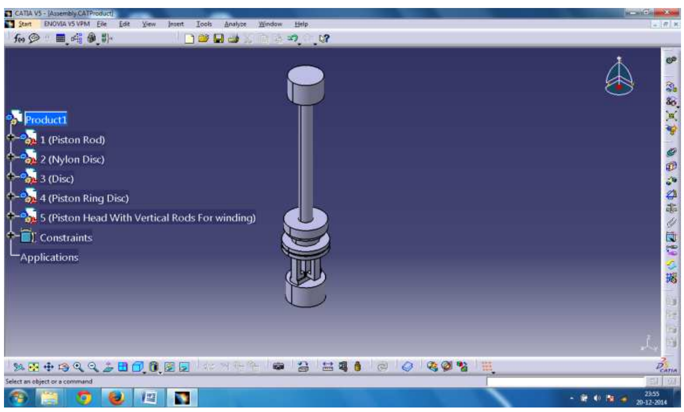


Figure 3: MR Damper 3-D View

METHODOLOGY

Experimental Setup

The construction of a MR linear damper is shown in Fig. The damper has a cylindrical shape and is filled with a MR fluid. The piston construction with an integrated coil ensures that, the magnetic field is focused within a gap, inside a volume of the active portion of the MR fluid. The damper operation is based on using the MR effect, which amounts to quick changes in the viscosity of the active portion of the fluid in the gap. In the absence of a magnetic field, the aggregates of magnetic particles are suspended in the carrier fluid, their magnetic moments are without any ordered structure and the resultant magnetic moment is equal to zero.

In the presence of an external field, the aggregates are polarized and their magnetic moments are arranged along the field lines. These aggregates form chain-like structures parallel to the field lines (perpendicular to the fluid flow direction), thereby increasing the shear stress and the fluid viscosity and restricting its motion. The magnetic energy required to form such structures increases due to the increase in the magnetic field. As a result, the fluid flow through the gap becomes limited, which draws increased hydraulic resistance for the piston movement and creates an additional damping force component, depending on the magnetic field (intensity of the current in the coil).

The total MR Damper experimental setup consists of following parts:

Table 1

a)	MR Fluid	b)	Cylindrical chamber
c)	Piston rod	d)	Frame
e)	Permanent magnet	f)	Convergent nozzle
g)	Weight (Load)	h)	Coil
i)	Electrical wire	j)	

MR Fluid

MR fluids belong to a group of fluids which are non-Newtonian, rheologically stable, with shear yield strength, and are controlled by a magnetic field. These fluids are non-colloidal suspensions with magnetic particles of high concentration in a non-magnetic fluid carrier. The materials applied as the magnetic particles are soft magnetic compounds. Water, silicon, mineral or synthetic oil and glycerol act as fluid carriers. Magnetic particles have a diameter of between 0.5 μm and 8 μm, therefore the MR fluids are also known as micro fluids.

The rheological properties of MR fluids depend on the concentration of magnetic particles, their size, shape, and properties of fluid carriers, magnetic field intensity, temperature and also other factors. For better results, engine oil with adding of magnetic particles of having size 100 meshes is used as a MR fluid.

Cylindrical Chamber

It is cylindrical in cross section, and all the other parts such as piston, piston rod, magnetic coil and wire are enclosed within the chamber and act as protection to all the remaining parts. It is usually constructed with a fiber, which is transparent to visualize the damping effects within the damper, to measure the height of MR liquid before the magnetic field applied and after. The diameter of the cylindrical chamber is 110 mm, and also, it affects the performance of damper to evaluate the damper performance.

Figure 4: Cylinder

Piston Rod

Piston rod is a long cylindrical rod having length of 203 mm, which consists of a piston head at one end and enclosed within the cylindrical chamber. The piston head is having diameter of 108 mm and it consists of windings for generating magnetic field. The other end of the piston rod is connected to applying load, externally. Whenever the load is applied on the piston rod, the piston moves forward and creates some resistance force by the fluid to the piston within the magnetic field.

Figure 5: Piston Rod

Frame

Frame is a structure, which supports all the parts of the MR Damper. The frame is a rigid structure, connected by means of bolt and nut arrangements and welded at corner joints, in order to get rigidness for supporting the entire parts of the damper. It consists of a vertical column, where, the weight is mounted to apply load on the piston rod at certain height.

Experimental Procedure

Steps Involved in the Experiment

Initially, the cylindrical chamber is filled with MR fluid consists of Engine oil and magnetic particles of size 100 mesh. Mount the piston inside the cylindrical chamber. Take initial readings when the piston is at the top and measure the lengths from the bottom of the cylinder. Release the piston without applying any load and without applying magnetic field to the fluid. Then, piston moves downwards into the fluid due to its own self weight. Mark the readings and measure the lengths from bottom of the cylinder to the piston head and liquid level in the cylindrical chamber. Repeat the same procedure for without load and with magnetic field and measure the corresponding readings. Now, apply a load of 5.6 kg on the piston without applying magnetic field, therefore, the piston moves downwards into the fluid due to the application

of load and measure the readings, correspondingly. Repeat the same procedure for different loads and with and without magnetic field and measure the readings, accordingly.

Figure 6: MR Damper Structure

RESULTS AND DISCUSSIONS

Initially, the experiment is conducted in the presence of magnetic field and allowed the fluid to pass through magnetic field. Therefore, it changes its characteristics of fluid and gives good damping characteristics in order to control the vibration of the system. In the similar passion, later allowed the fluid through without magnetic field, and then compared both the results.

The Results obtained for the fluid at time interval t, passed through, with magnetic field and without magnetic field.

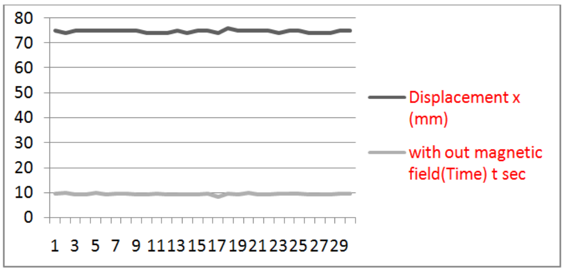


Figure 7: Identified Plots without Magnetic Field

Estimated hysteresis characteristics of MR damper results obtained at time interval t, without magnetic field, and observed damping is low 0.2 %.

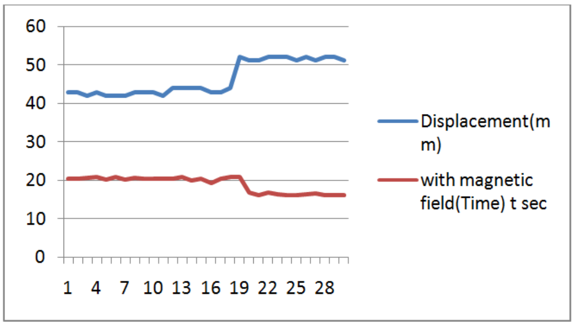


Figure 8: Identified Plots with Magnetic Field

Estimated hysteresis characteristics of MR damper results obtained at time interval t, with magnetic field, and

observed damping factor comparatively very high to 10% increase.

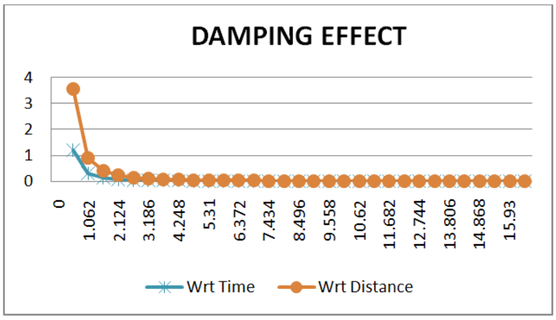


Figure 9: Identified Plots at 10 Kg without Magnetic Field

Estimated hysteresis characteristics of MR damping effect results obtained at time interval t, without magnetic field, and observed damping is less with a difference of 2%

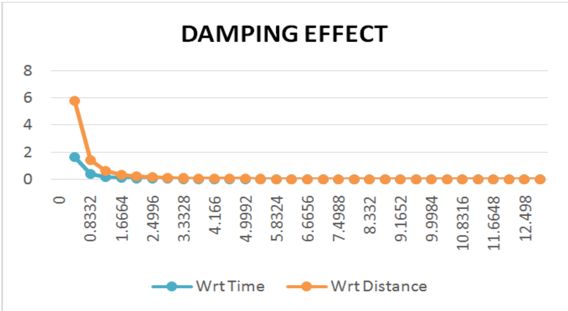


Figure 10: Identified Plots at 10 Kg with Magnetic Field Graph

Estimated hysteresis characteristics of MR damper results obtained at time interval t, with magnetic field, and observed damping factor comparatively very high to 4% increase. It is comparatively high as compared without magnetic field.

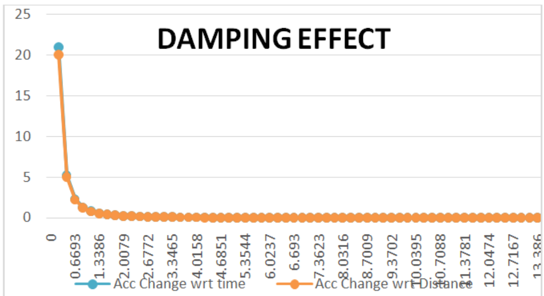


Figure 11: 16 Identified Plots at 16Kg without Magnetic field Graph

Estimated hysteresis characteristics of MR damper results obtained at time interval t, without magnetic field, and observed damping is very low.

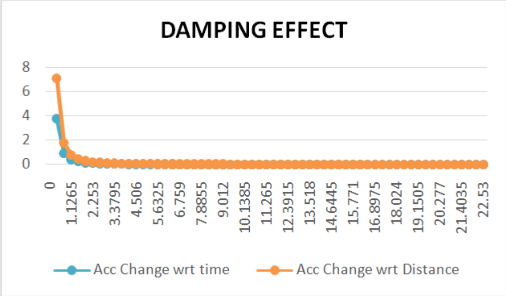


Figure 12: Identified Plots 16 Kg with Magnetic Field Graph

Estimated hysteresis characteristics of MR damper results obtained at time interval t, with magnetic field, and observed damping factor is comparatively very high compared to without magnetic field effect. That is raised to 3% increase.

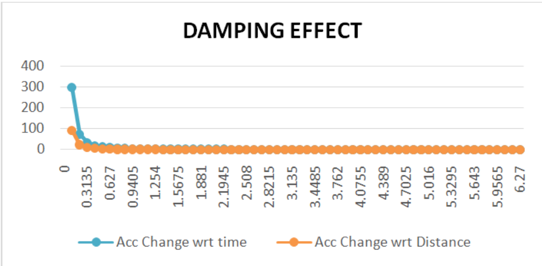


Figure 13: Identified Plots 22 Kg without Magnetic Field Graph

Estimated hysteresis characteristics of MR damper results obtained at time interval t, without magnetic field, and observed damping is comparatively nearer values, but the damping effect is low as compared with magnetic field graph.

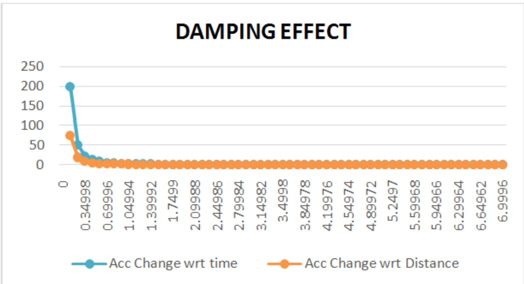


Figure 14: 22 Identified Plots Kg with Magnetic Field Graph

Estimated hysteresis characteristics of MR damper results obtained at time interval t, with magnetic field, and observed damping factor is comparatively nearer to values effect without magnetic field.

CONCLUSIONS

An experimental setup with damper is built and studied in laboratory. From this study, we can conclude that a static model coupled with damper can significantly reduce the vibration of the system by the application of magnetic field to the fluid, as per some considerable applied load. By the application of the magnetic field, the effect of damping has been increased and able to reduce the vibrations caused by the body with greater extent. It is observed in the graph and clearly shown that; the rate of acceleration has been decreased, which indicates that the damping coefficient has been increased with respect to time and with respect to displacement, accordingly.

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